DARK ENERGY SURVEY

DES Photometric Calibrations: General, Y1A1, & atmCam

Douglas L. Tucker

DES Collaboration Meeting
Sussex
20 October 2014

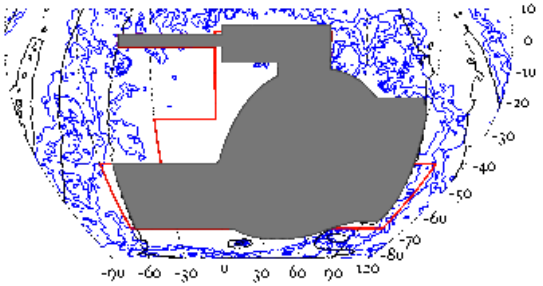
DES Photometric Calibration Requirements (5-year, coadded)

DARK ENERGY SURVEY

1. **Internal:** 2% rms on scales of 0.05° - 4°.

   Goals: 1% rms and/or over 160° in RA, 30° in DEC.

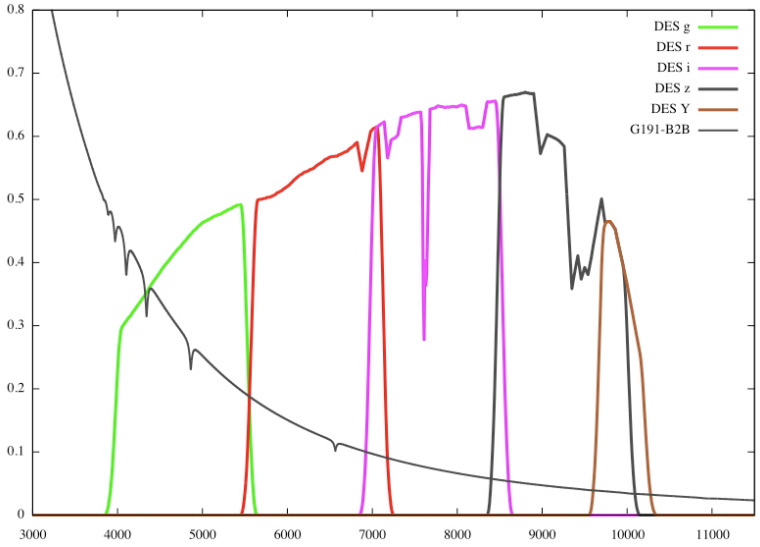
   (We will focus mostly on this req. in this talk.)



2. **Absolute Color:** 0.5% (*g-r, r-i, i-z*); 1% (*z-Y*).

   Averaged over 100 objects scattered over the focal plane.

   "Between-filters" calibration.



3. **Absolute Flux:** 0.5% in *i*-band.

   Relative to standard star BD+17 4708.

   Zeropointing the overall filter system.

Yearly Science Goals: Photom. Calibrations

(DESDM talk at May 2014 Collaboration Meeting: DES-docdb#7832)

DARK ENERGY SURVEY

- Year 1 (Y1A1): <4% relative photometry
- Year 2 (Y2A1): <3% photometry
- Year 3 (Y3A1): 2% photometry
- Year 4 (Y4A1): <2% photometry across large areas
- Year 5 (Y5A1): attempt 1% (stretch goal) photometry

We will likely meet all these goals early.

DARK ENERGY
SURVEY

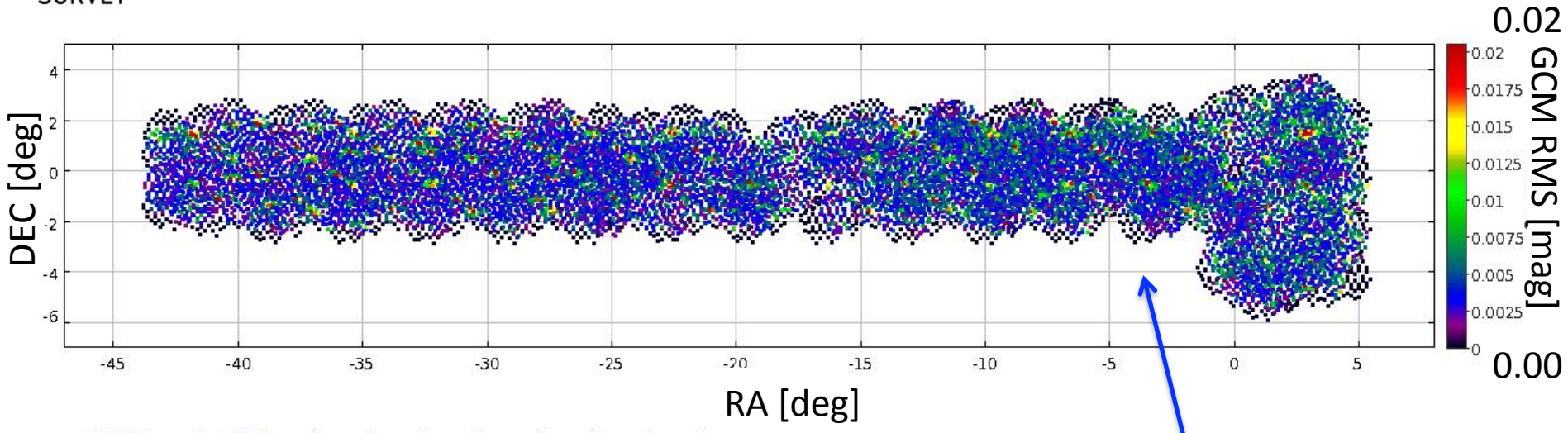
Stripe 82 Equatorial Area for Y1A1

- ***Essentially complete overlap with SDSS DR10.***
- → "Punted" and just used SDSS DR10 (transformed into the DES AB mag system) as local tertiary standards.
- Performed a single-pass Global Calibration Module (GCM)* solution, solving for photometric zeropoints on a CCD image by CCD image basis.

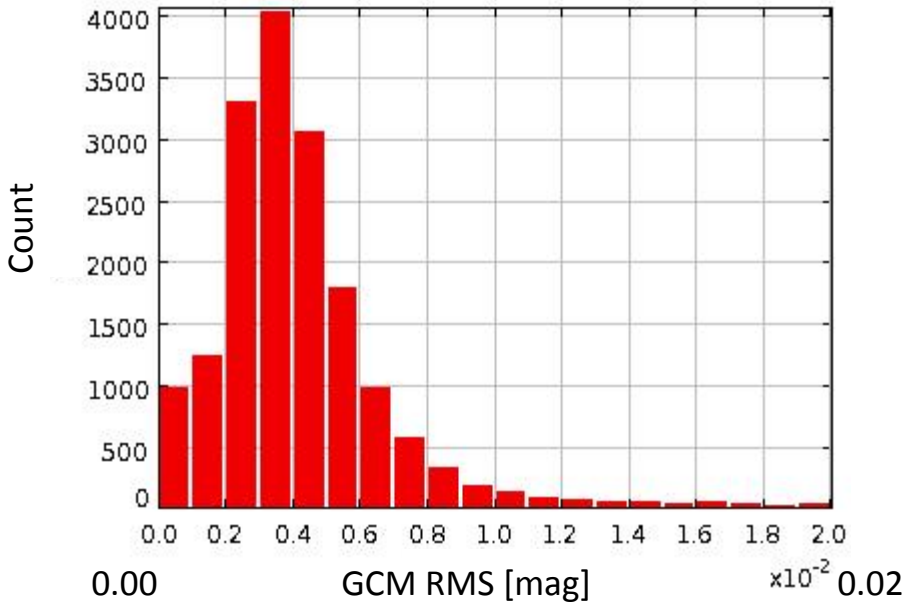
*GCM, as with most current global calibration methods, uses the overlaps between images to estimate the photometric zeropoints for individual images.

Y1A1 Equatorial Area: g-band GCM RMS's (internal errors)

DARK ENERGY SURVEY



Each "point" is an Individual CCD image



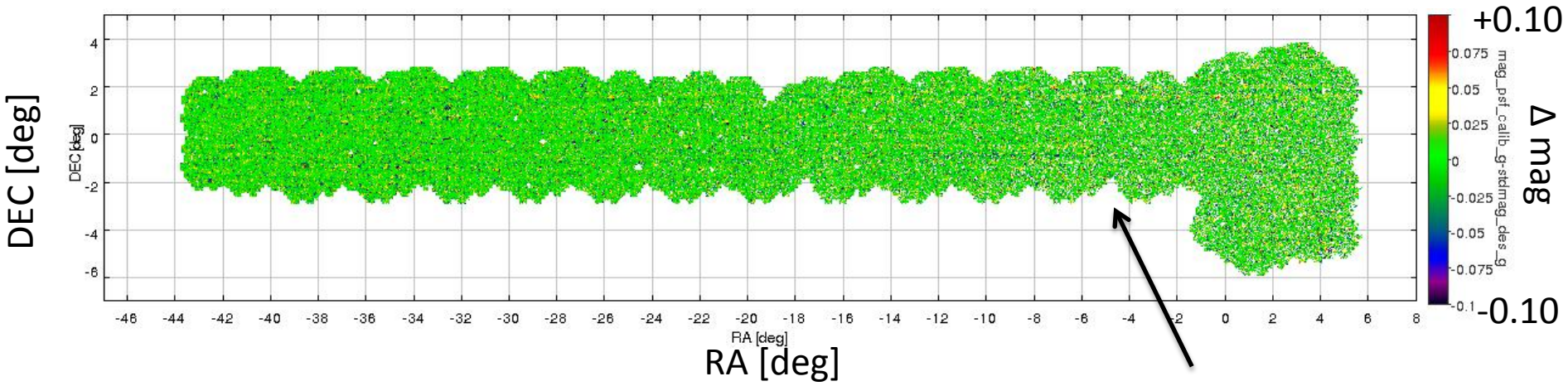
RMS of overall solution: 0.0055 mag (0.55%)

← (Note that the x-axis is in units of 0.01 mag)

Y1A1 Equatorial Area: Cross-Check for Systematic Errors

DARK ENERGY SURVEY

GCM-calibrated mag_psf minus stdmag* vs. (RA,DEC):
g-band



Each point is an individual star

RMS of Δmag: <0.02mag (<2%)

*stdmag = SDSS DR10 mag transformed to DES AB mag

SPT Area for Y1A1

- Not much overlap with previously calibrated grizY standards stars
- Needed to create local tertiary standards* from PSM solutions or from other sources.
- Calibrated SPTE in two steps:

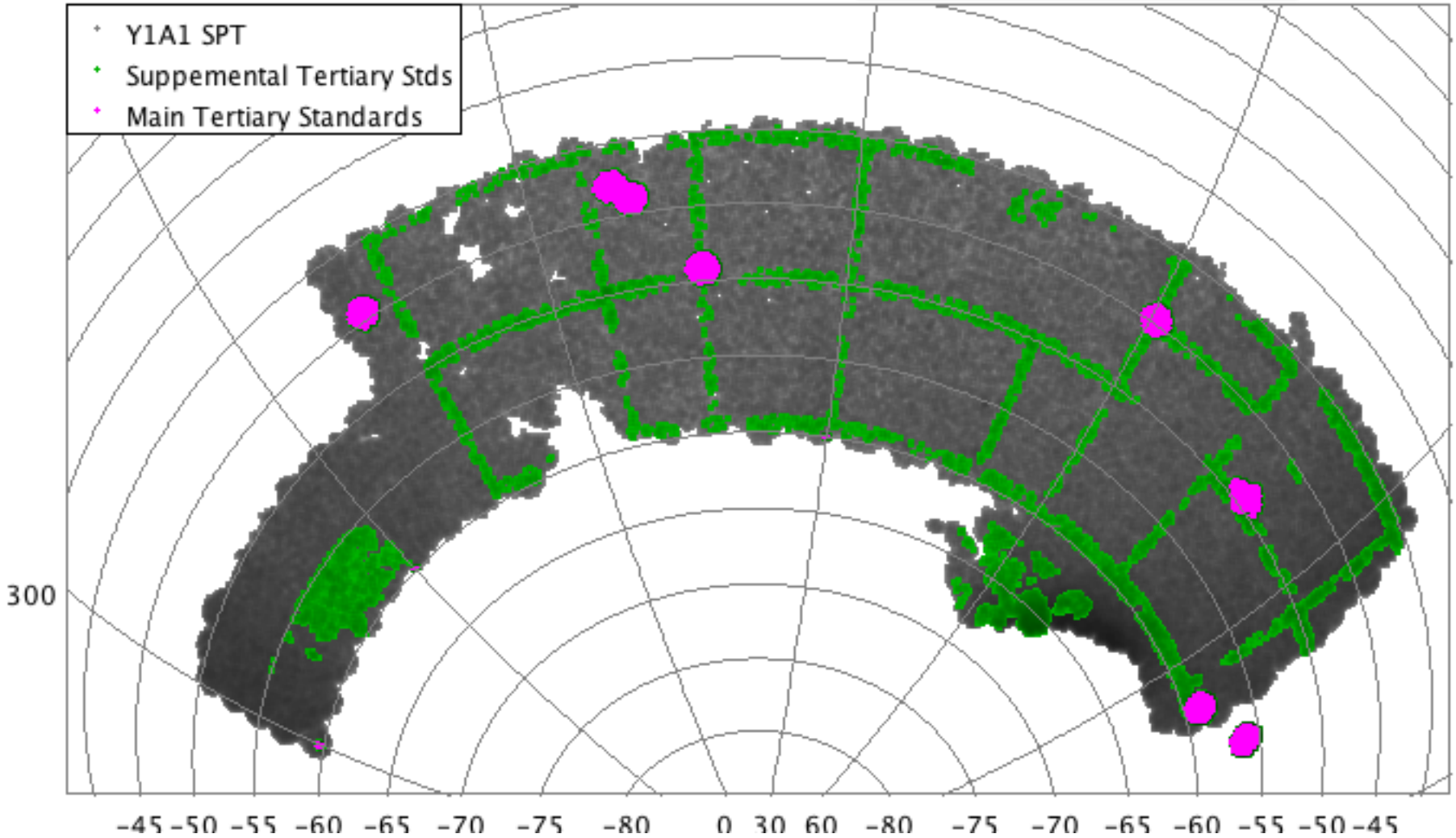
1. Calibrated photometric exposures on an exposure-by-exposure basis, tossing out dome occluded/non-photometric exposures iteratively, and tying to the local tertiary standards, creating a set of “quaternary standards” spanning nearly the full SPT footprint in RA,DEC.
2. Calibrated all SPT data (non-photometric/dome-occluded exposures as well as photometric exposures) on a CCD image by CCD image basis by tying to quaternary standards from Step 1.

(*Thanks to Sam Wyatt for creating these tertiaries!)

Y1A1 SPT Area:
Tertiary Standards (Main & Supplementary)

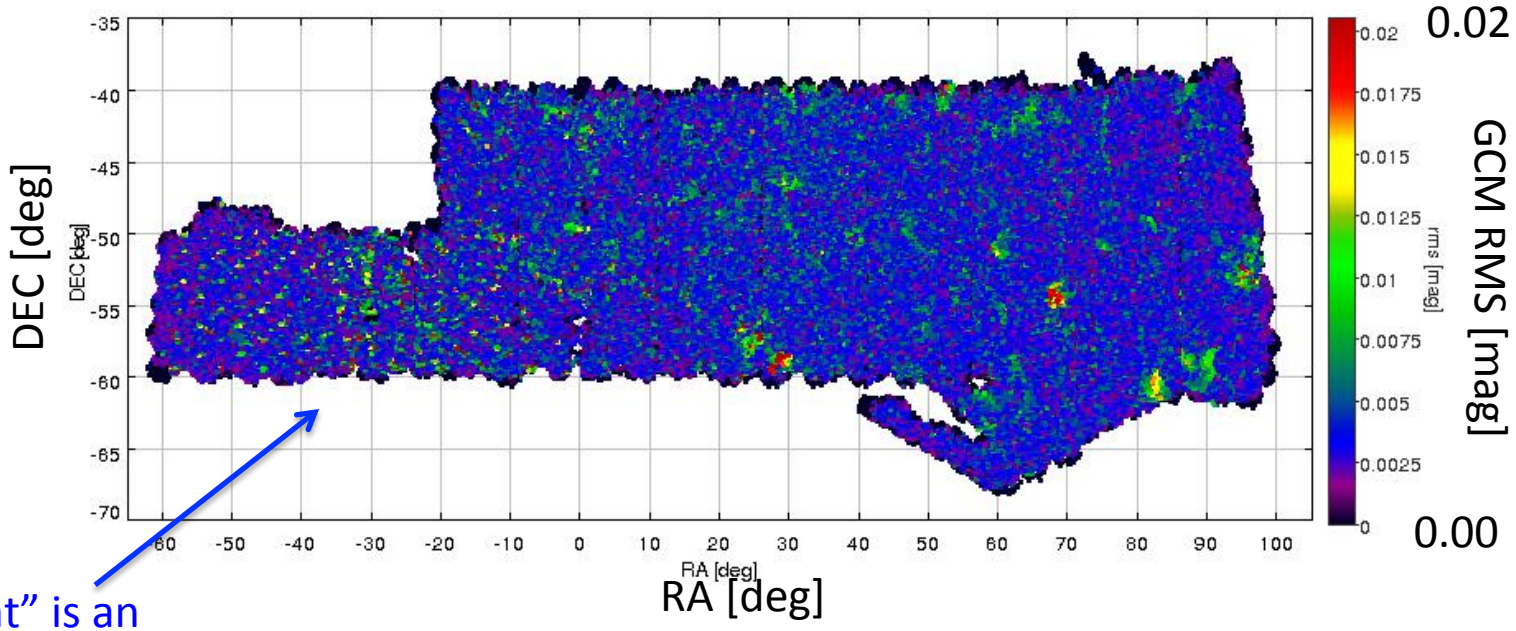
DARK ENERGY SURVEY

Thanks, RASICAM!

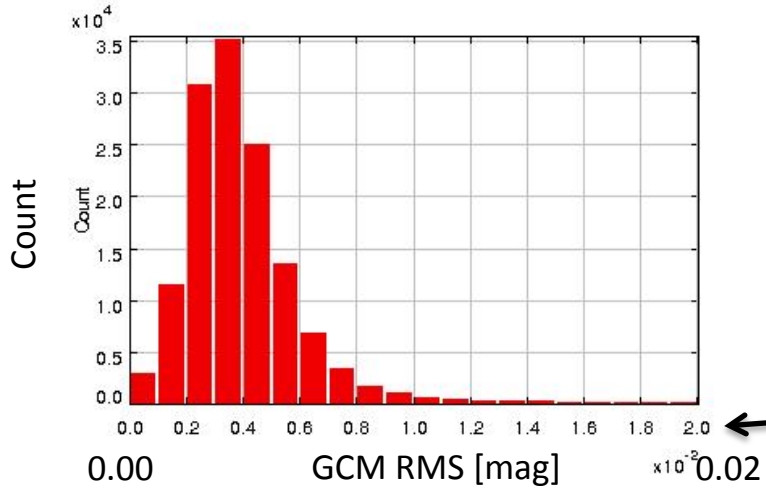


Y1A1 SPT Area: g-band GCM RMS's (internal errors)

DARK ENERGY SURVEY



Each "point" is an individual CCD image

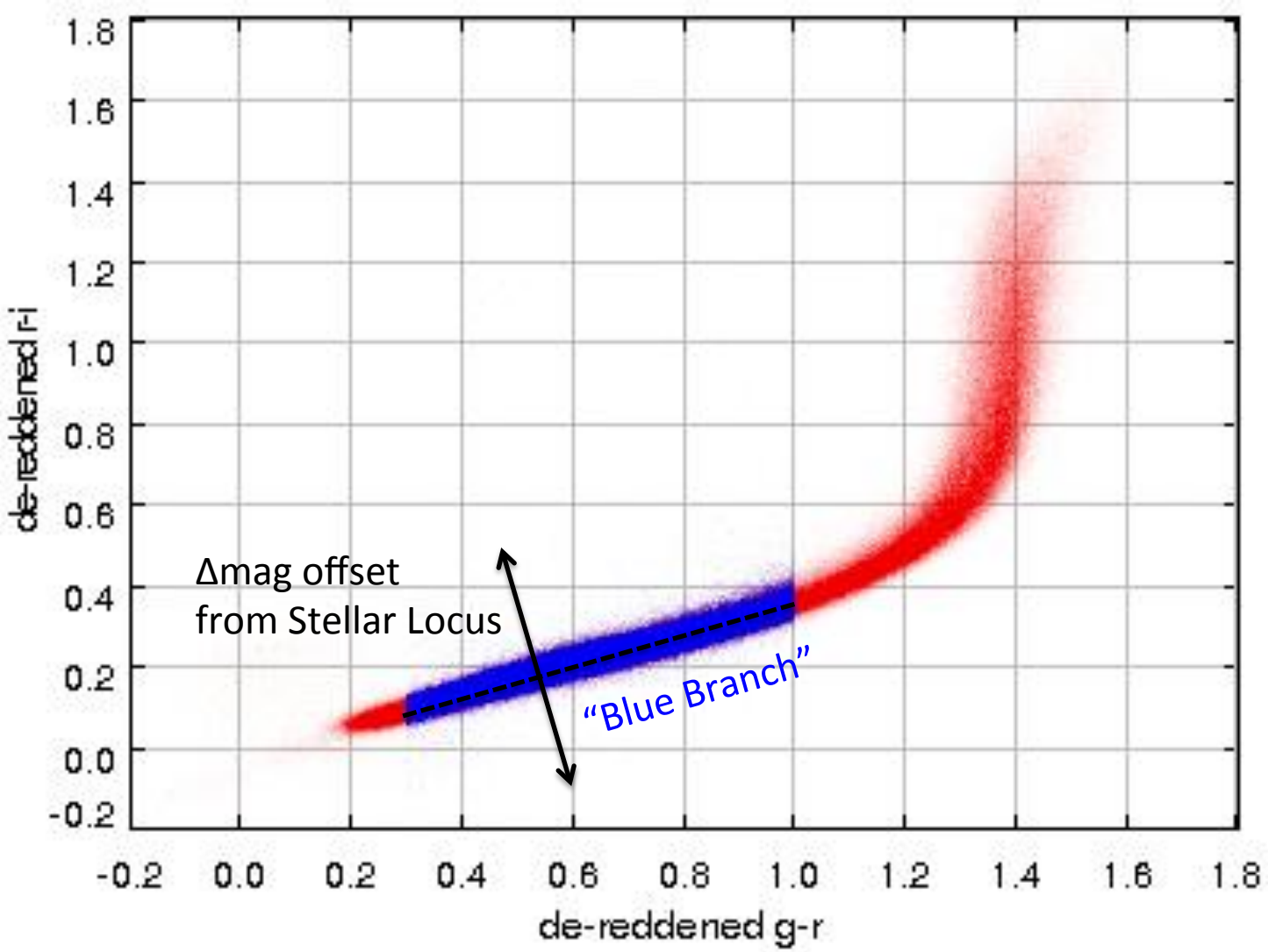


RMS of overall solution: c. 0.005 mag (0.5%)

(Note that the x-axis is in units of 0.01 mag)

Y1A1 SPT Area: External Check using a "Poor Man's SLR"

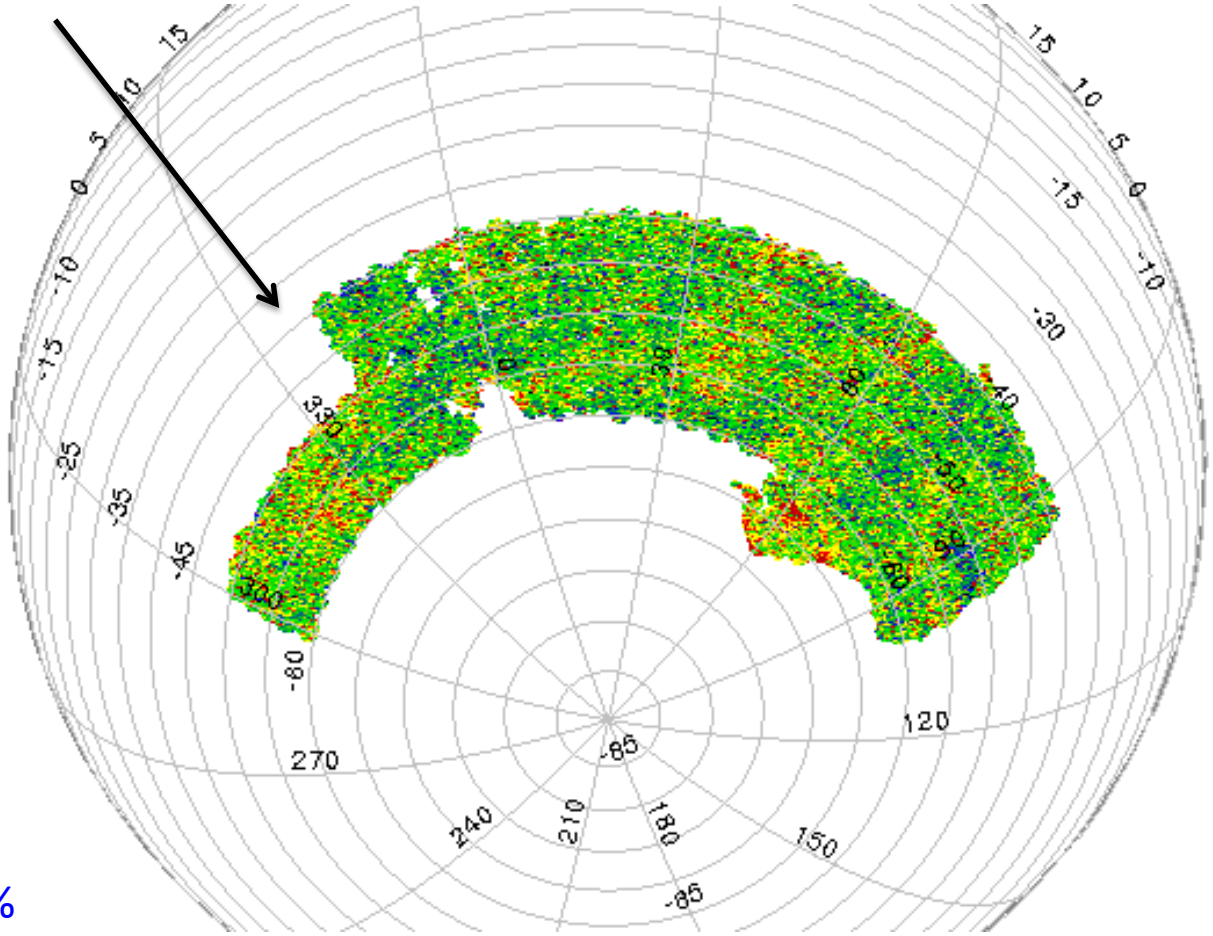
DARK ENERGY SURVEY

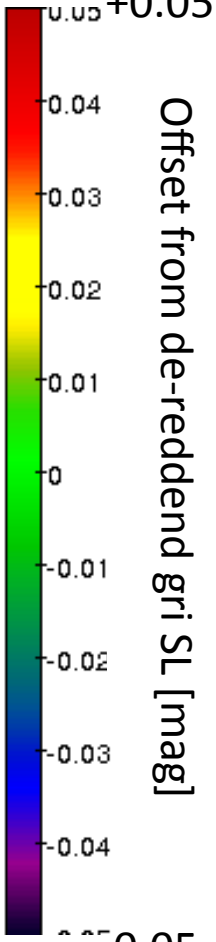


Y1A1 SPT Area: External Check using a "Poor Man's SLR"

DARK ENERGY SURVEY

Each point is an individual star





1σ RMS:

- gri: 1.9%
- riz: 2.8%
- izY: 2.6%

(Thanks, Brian Yanny!)

DARK ENERGY
SURVEY

SN Areas for Y1A1

(plus nightly standard star fields, plus special photo-z fields…)

- Lots of overlap with previously calibrated DES grizY tertiary standards.
- Update previously calibrated DES grizY tertiary standards* using new data from Year 1.
- Perform a single-pass GCM solution, solving for photometric zeropoints on a CCD image by CCD image basis.
- **Not yet done.**

(*Thanks to Sam Wyatt for creating these tertiaries!)

DARK ENERGY SURVEY

Y1A1 Calibrations Caveats

- These are single-epoch calibrations.
  - The coadd process *could* in principle imprint additional errors.
  - One reason to tie the Y1A1_STRIPE82 directly to SDSS Stripe 82 (transformed to DES) is to try to isolate any problems in the calibrations in the single-epoch data from those in the coadds.

- GCM calibrations – like SDSS calibrations – do ***not*** include interstellar reddening.
  - This is true even when we are not tying calibrations directory to SDSS as with the Y1A1_STRIPE82 data set.
  - So don't forget to apply interstellar reddening corrections to the data if they are important to your science!
  - SLR calibrations *do* include interstellar reddening, so be careful when comparing between the two types of calibration!

DARK ENERGY SURVEY

The Future of Global Calibrations…

The Global Calibrations Challenge

1. Purpose: To test out new and improved global calibration codes for use in the Year 2 processing campaigns and beyond.
2. Wiki: https://cdcvs.fnal.gov/redmine/projects/descalibration/wiki/Global_Calibrations_Challenge
3. **Sussex sessions: Wednesday @ 17:00 and Thursday @17:00**

Codes taking part in the Challenge:

Jim Annis's YaCal (DES-doc#7690)

Anne Bauer's Ubercal/Nebencal (DES-doc#7687)

Gary Bernstein's PhotoFit (DES-doc#7689)

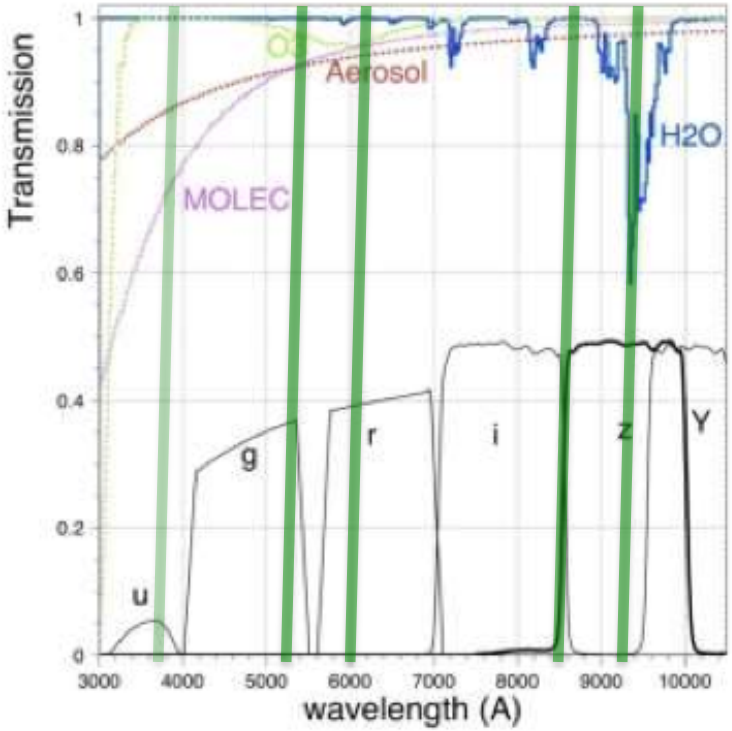
Dave Burke's Forward Calibration (DES-doc#7688)

aTmCam:

An Atmospheric Transmission Monitoring Camera for the DES

DARK ENERGY SURVEY

Installed in August and operating since early September!



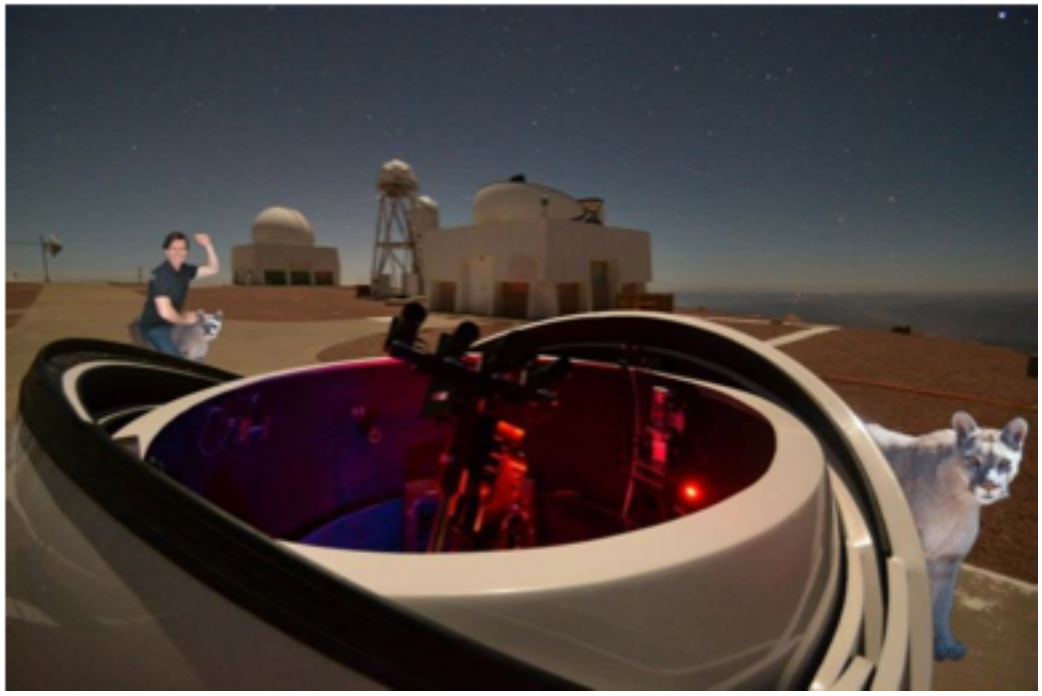


Photo credit: B. Nord; atmCat mascot suggested by A. Walker

atmCam team: Ting Li, Jennifer Marshall, Daniel Nagasawa, Nicholas Mondrik, Darren DePoy, David James (+ CTIO TelOps)

See Ting's atmCam talks in the Tues. DES Operations session and in the Wed. Calibration session.

DARK ENERGY
SURVEY

Extra Slides

From the Scientific Requirements Document
(DES-doc#20-v32: sciReq-9.86, 10 June 2010)

DARK ENERGY SURVEY

R-10 For each of the *grizY* bandpasses of the wide-area survey, the fluctuations in the spatially varying systematic component of the magnitude error in the final co-added catalog must be smaller than 2% rms over scales from 0.05 to 4 degrees.

R-11 The color zeropoints between the survey fiducial bandpasses (*g-r, r-i, i-z*) must be known to 0.5% rms. The *z-Y* color zeropoint shall be known to 1% rms.

R-12 The i-band magnitude zeropoint relative to BD+17, and therefore the AB system, must be known to 0.5% rms.

R-13 The system response curves (CCD + filter + lenses + mirror + atmosphere at 1.2 airmasses) must be known with sufficient precision that the synthesized *grizY* magnitudes of any astronomical object with a calibrated spectrum agree with the measured magnitudes to within 2%. When averaged over 100 calibrating objects randomly distributed over the focal plane, the residuals in magnitudes due to uncertain system response curves should be < 0.5% rms.

For 5-year Survey

G-4 A goal of the survey is to achieve **R-10** at the enhanced level of 1% for the final co-added catalog.

G-5 A goal of the survey is to achieve **R-10** over 160 degrees of Right Ascension and 30 degrees of Declination.

Enhanced goals

17

Overall DES Calibrations Plan in 5 Points

DARK ENERGY SURVEY

1. Instrumental Calibration (Nightly & Periodic): Create biases, dome flats, linearity curves, cross-talk coefficients, system response maps.

2. Photometric Monitoring: Monitor sky conditions with 10μm All-Sky Cloud Camera and the GPS and atmCam atmospheric transmission monitors.

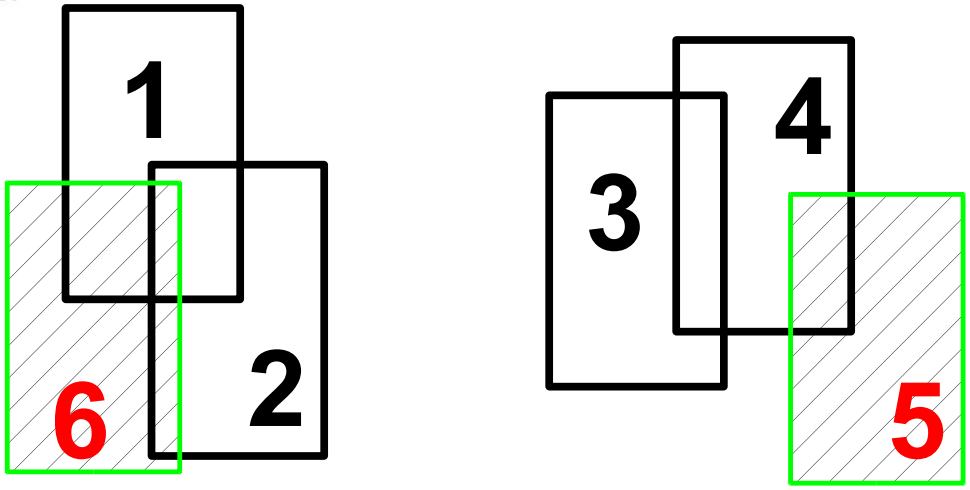
3. Nightly and Intermediate Calibrations: Observe standard star fields with DECam during evening and morning twilight and at least once in the middle of the night; fit photometric equation; apply the results to the data.

4. Global Relative Calibrations: Use the extensive overlaps between exposures over multiple tilings to tie together the DES photometry onto an internally consistent system across the entire DES footprint.

5. Global Absolute Calibrations: Use DECam observations of spectro-photometric standards in combination with measurements of the full DECam system response map to tie the DES photometry onto an AB magnitude system.

Global Calibration Module (GCM): Field-to-Field Zeropoints

DARK ENERGY SURVEY



A Generic Example:
Frames 5 & 6 are calibrated.
The others are uncalibrated.

- Method used by Oxford-Dartmouth Thirty Degree Survey (MacDonald et al. 2004)
- Developed by Glazebrook et al. (1994) for an imaging K-band survey

- Consider n frames, of which (1, …, m) are calibrated and (m+1,…,n) are uncalibrated.
- Let $\Delta_{ij} = \langle mag_i - mag_j \rangle_{pairs}$ (note $\Delta_{ij} = -\Delta_{ji}$).
- Let ZP_i be the floating zero-point of frame i, but fixing $ZP_i = 0$ if $i > m$.
- Let $\theta_{ij} = 1$ if frames i and j overlap or if i = j; otherwise let $\theta_{ij} = 0$.
- Minimize $S = \Sigma\Sigma\ \theta_{ij} (\Delta_{ij} + ZP_i - ZP_j)^2$

Global Relative Calibration Steps for Y1A1

(using the Global Calibrations Module, or GCM)

DARK ENERGY SURVEY

1. **Pre-Calibrate:** create a set of local DES tertiary standards in each isolated area (Stripe 82 equatorial area, SPT areas, SN areas) to tie the zeropoints to the DES AB system as well as to anchor the relative calibrations against gradients.

2. **StarMatch:** find all unique matches for star detections in the image-to-image overlaps and between star detections and the local tertiary standards.

3. **GCM-zeropoint:** solve for the photometric zeropoints for all the images observed in a given isolated Y1P1 area.

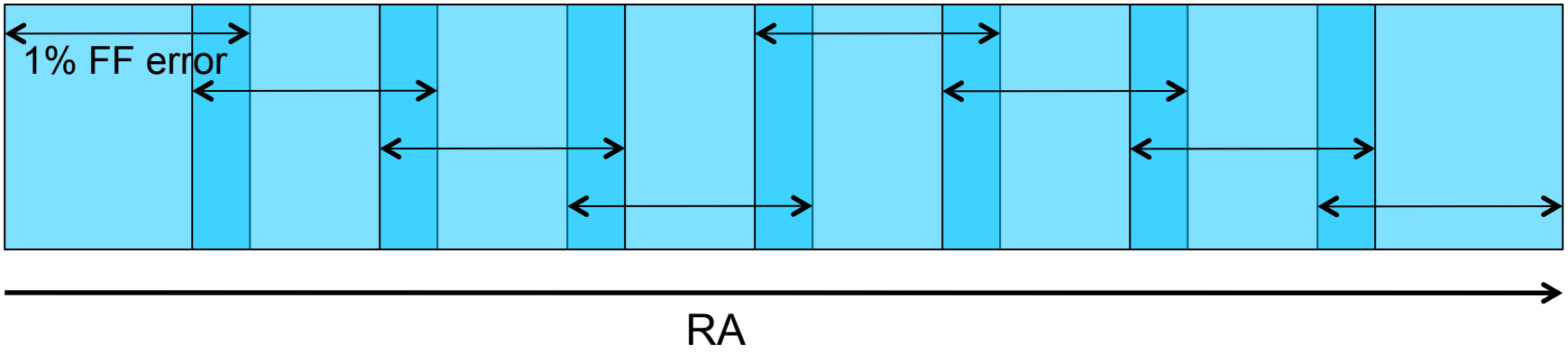
4. **NCSA Handoff:** hand off list of ccd image zeropoints to NCSA for uploading into database.

Statistical vs. Systematic Errors

DARK ENERGY SURVEY

- It is possible to get a statistically good solution from a relative calibrations solver (like GCM) but still have large systematic errors.

- Consider the a long, thin strip in RA, with a 1% flat fielding error (edge-to-edge) from West to East:



- One could still get a statistically tight offset between fields from the overlaps, but still end up with large systematic errors.

DARK ENERGY SURVEY

Global Calibrations Challenge

Data sets to cover (still under some discussion):

- **Y1A1 Equatorial ("Stripe82") Area** as defined by Robert Gruendl's Y1A1_STRIPE82/ Y1A1_STRIPE_NOCAL exposure tags. (SDSS provides a measure of "truth".)
- **Either the Y1A1 SPTE or the Y1A1 SPTW Area**, to be defined by Robert Gruendl's exposure tags for these areas. (No "truth", but larger area.)
- If time, Y1A1 SN data, including **SN exposures that do not meet the coadd image quality cuts** but are still needed by the SN group for differential photometry, etc.
- If time, **SV-A1 SPTE**. (Goes to full 5-year DES depth, but data have more problems compared with later data)

Priority of filter bands to test (still under some discussion):

- For the Y1A1 Equatorial Area: griz (Y if time)
- For the Y1A1 SPT Area: r, z (others if time)
- For the SN fields: TBD, but probably griz
- For the SV-A1 SPTE Area: TBD

DARK ENERGY SURVEY

Global Calibrations Challenge

Metrics

- Repeatability (single-image rms errors)
- Systematics (comparison against "truth", for some value of "truth" -- e.g., against SDSS, which is "truth" to about 1-2%)
  - plots of systematics vs. position on the sky
- Completeness
  - number of filters with solved-for calibrations by the October Y2P1 decision deadline
  - fraction of images for which the code can supply zeropoints
- Others?

Future

- We will likely be refining the global calibrations algorithms up through the end of the survey.
- Possibly additional Global Calibration Challenges in Year 3 and beyond…